

# technical brief

## Membrane Pretreatment of Reclaimed Wastewater for Reverse Osmosis Desalination

*Energy Delivery & Utilization Division*

*Municipal Water and Wastewater Treatment Target*

### Summary

As populations grow and economies expand in the southwestern United States, local water utilities must deal with the dual problem of increased demand for limited water supplies and general deterioration of source water quality. In southern California, water agencies face the additional challenges of mitigating the environmental impacts of water transfers from northern California and the deleterious effects due to the rising salinity of the Colorado River. Moreover, in order to comply with federal mandates on the use of imported water, California must develop sustainable supplies of potable water from alternative sources.

In response, the Orange County Water and Sanitation Districts (OCWD & OCSD) have developed a wastewater reclamation project that would be implemented in three phases, beginning in the year 2003, and will ultimately produce 100,000 acre-feet per year (afy) ( $1.2 \times 10^8$  m<sup>3</sup>/y) of high quality water by the year 2020. This water will represent 20 percent of the fresh water supply used to recharge the Orange County groundwater basin, which provides up to 75 percent of the potable water for nearly two million county residents.

Advanced water treatment (AWT) processes based on microporous membranes, such as microfiltration (MF) and ultrafiltration (UF), followed by reverse osmosis (RO) have become the industry standard for the treatment of municipal wastewater in indirect potable reuse projects. The common feature in the design

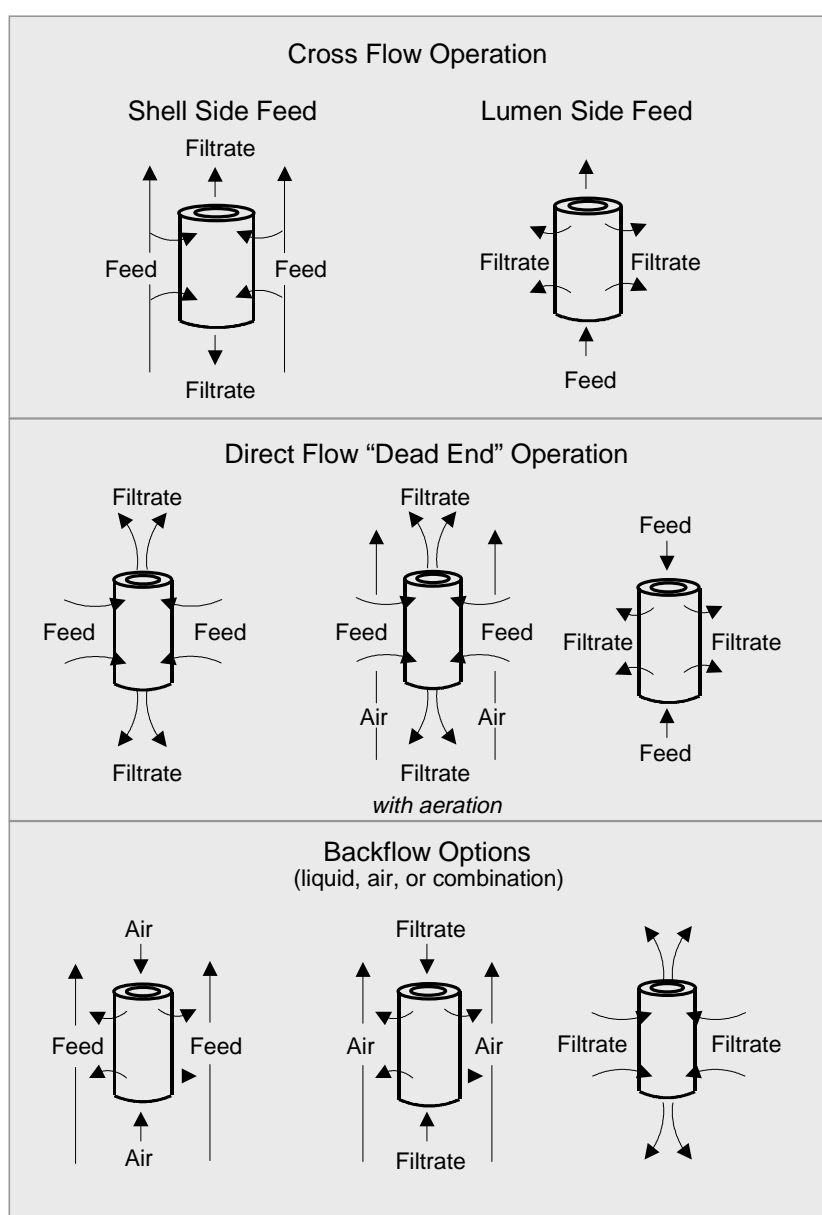


Figure 1. System configuration options for microporous hollow fiber membranes.

of such AWT facilities is the use of thin film composite membranes for the RO process; these membranes, configured in spiral wound elements, are produced in a standard size by several manufacturers. Conversely, there are variety of membrane types and system configurations available for the MF and UF processes that are required to treat the wastewater prior to RO. Consequently, the following data and observations have been compiled to identify the optimum features of a pretreatment membrane system for RO.

For the last two years, OCWD has been working with the California Energy Commission, EPRI, and Southern California Edison to evaluate different MF and UF pretreatment options for RO. The results to date of membrane treatment of clarified secondary effluent are promising and indicate:

- Low-pressure microporous membranes provide exceptional treatment prior to RO desalination.
- A 40 percent energy savings is possible if new membrane technology is used to replace existing treatment technology at OCWD's Water Factory 21 (WF21).
- Less residuals (sludge) are generated, thus improving residuals handling, processing, and disposal.

Future testing will focus on identifying the factors that lead to membrane failure and evaluating innovative membrane systems which can be retrofitted into existing wastewater treatment structures such as clarifiers and aeration basins.

### Project Background

Since 1967, OCWD has been reclaiming 10 million gallons per day (mgd) (38,000 m<sup>3</sup>/d) of secondary effluent from OCSD at WF21 for the replenishment of the local groundwater basin. Treatment at WF21 consists of pretreatment with a five-stage clarification process followed by RO using cellulose acetate membranes. Operating pressure of the RO system is approximately 300 pounds per square inch (psi) (2070 kPa). A three-stage process is used for handling the lime residuals (sludge). The operating costs of the pretreatment system are high because of high lime use (approximately one ton (907.2 kg) of lime is used to treat one million gallons of water (3.8 x 10<sup>6</sup> L)) and



Membrane technologies can be used for a variety of water and wastewater applications.

residuals processing and disposal. The lime system also occupies a large land area, thus limiting the potential for facilities expansion.

OCSD, which is located adjacent to OCWD, treats about 250 mgd (946,350 m<sup>3</sup>/d) of wastewater. High concentrations of dissolved salts (salinity), ranging from 900 to 1,300 milligrams per liter (mg/L) of total dissolved solids (TDS), limit the reclamation potential. Contaminants such as nitrates and organic matter are also present as well as bacteria and viruses. If affordable and effective advanced wastewater treatment is employed to reduce TDS levels below 500 mg/L, a major portion of this wastewater can be reclaimed and used for further groundwater replenishment and other purposes.

Issues that need resolution relate to the removal of undesirable constituents in the wastewater to be reclaimed. Conventional treatment technologies can remove most of these constituents, but they cannot reduce dissolved salts. Dissolved salts are present in fresh water, and their concentrations in wastewater are further increased by municipal and industrial use. Therefore,

advanced treatment systems that include some form of desalination, namely reverse osmosis (RO), must be employed.

Because RO uses nearly impermeable membranes, the feed water to the RO unit must be pretreated to remove matter that fouls the membrane and thus curtails production. Conventional technology using physical/chemical treatment is one method of pretreatment. Recent developments in low-pressure membrane technology, however, offer opportunities for providing alternative energy-efficient and cost-effective solutions for pretreating RO feed water. Research is required, however, to demonstrate the performance of membrane systems in comparison to conventional physical/chemical treatment.

The objective of this project is to evaluate the performance of two membrane treatment technologies—microfiltration (MF) and ultrafiltration (UF) — for pretreating reclaimed wastewater prior to treatment by RO. Issues to be explored include: (1) the potential for and degree of fouling, (2) energy consumption, and (3) characteristics and disposal of residuals from low-pressure membranes.

## Technology Overview

Low pressure membrane processes such as MF and UF are alternatives to the high lime process for RO pretreatment. MF and UF are pressure-driven, liquid-phase processes that use hydraulic pressure to force water molecules through microporous membranes. Impurities are retained and concentrate in the feed water, which becomes the reject water or concentrate stream. The permeate, the water that passes through the membrane, is recovered as product water. MF and UF are used in both water and wastewater treatment as alternatives to conventional solids separation processes such as granular media filtration and clarification by chemical addition, flocculation, and settling.

MF and UF remove large organic molecules, large colloidal particles, protozoa, and bacteria. MF performs as a porous barrier to reduce turbidity and some types of colloidal suspensions. UF offers higher removals than MF, but operates at higher pressures. In wastewater reclamation, MF or UF can be used in tandem with RO to remove material that would foul the less permeable RO membranes. Because MF and UF use more permeable membranes than RO, they operate at lower pressures. MF pressures range from 1 to 15 pounds per square inch (psi) (6.9 to 103.5 kPa), while UF pressures are from 10 to 100 psi (69 to 690 kPa). Electric motor-driven pumps are used to pressurize the feed water.

As compared to the conventional lime process, MF and UF occupy a smaller area, require less energy, generate less residuals, generally require less maintenance, and are more effective at removing precursors to biological fouling. MF and UF processes also produce a better effluent of consistent quality, resulting in less chemical and biological fouling of RO membranes.

Membranes selected by OCWD for testing are hollow fiber membrane elements that are either housed in a module (essentially a pressure vessel) or immersed in a tank or a water treatment basin.

For membrane elements housed in a module, the feed stream can contact either the inner (lumen) or outer (shell) surface of the fiber. As shown on Figure 1, the membrane system can be operated in either direct or cross flow filtration mode. In the direct mode, the feed water flow is normal

(perpendicular) to the membrane surface, and suspended solids are retained on the membrane surface. Periodically, the flow is stopped, and the membrane surface is backwashed. In the cross flow mode, the feed stream is pumped across the membrane surface. A velocity gradient is maintained across membrane surface that facilitates removal of the accumulated solids.

Membrane elements immersed in a tank are operated in the direct filtration mode at very low pressure. The lumens of the hollow fibers are directly connected, via a manifold, to the suction side of a pump. When the pump operates, a vacuum on the lumen side draws filtered water through the walls of the fiber. Some forms of immersed membrane design incorporate an air scour system for removal and transport of the retained material.

MF process recovery is a function of the permeate flow rate, length of filtration cycle, and the volume of water used in a backwash. For surface waters, the filtration cycle is usually 30 minutes with a process recovery of 95 to 97 percent. In wastewater applications, the permeate flow is at least 20 percent lower than surface water applications, and the membranes are backwashed every 20 minutes. The combination of decreased flow and length of filtration cycle lowers the recovery to 85 to 90 percent.

## Current Status of Research

Testing was conducted on treated wastewaters from OCSD's Plant No. 1. The treated wastewaters were: (1) effluent from primary clarifiers, whose clarification was enhanced by the addition of ferric chloride and polymer; (2) clarified effluent from a high-purity oxygen activated sludge plant; and (3) unclarified effluent from the activated sludge plant.

From the testing results to date, the conclusions are:

- Low pressure microporous membranes provide exceptional pretreatment for RO on clarified secondary effluent. Permeate from the membranes typically had turbidities of less than 0.3 NTU and suspended solids concentrations of less than 1.0 mg/L.
- When operating continuously on clarified secondary effluent, the flux rate for the low pressure membranes ranged

between 14 and 33 gallons per square foot per day (gfd) (570 to 1343 L/m<sup>2</sup>/d), depending on the membrane type. (Flux is the amount of water or salt that passes through a unit area of membrane).

- It was possible to increase the flux rate by 50 to 100 percent for periods of 24 to 48 hours without irreversibly fouling the membranes or impacting the permeate water quality.
- Membranes immersed in a tank containing clarified secondary effluent and operated in a suction mode had 90 to 97 percent recovery rates. In comparison, recovery rates for membrane systems contained in a pressure vessels (modules) ranged from 87 to 90 percent.
- The interval time between chemical cleaning ranged from two to four weeks depending on the cleaning regimen used.
- If the existing reclamation process was changed from lime treatment and cellulose acetate RO membranes to MF and thin film RO membranes, the operating pressures would be reduced from 300 psi (2070 kPa) to approximately 180 psi (1242 kPa). This represents an energy savings of 1.34 kWh/1,000 gallons (437 kWh/ac-ft (3.54 x 10<sup>-4</sup> kWh/L)).
- The best option for the treatment of residuals from low pressure membranes is the use of a second stage membrane to concentrate the backwash. A second stage membrane reduced backwash volume by 85 percent and produced an effluent suitable for processing by RO.

## Ongoing Research Activities

Future activities include identifying factors that influence fiber breakage in membranes and evaluating non-aerated suction-driven membranes for microfiltration. The membrane breakage investigation will analyze the mechanical properties of the membrane including the type of material, method of construction, and effect of duration of usage. Although aerated suction-driven membranes were successful in suspended solids removal, they exhibited high rates of fouling that caused frequent backwashing. Non-aerated suction-driven membranes will be tested to determine if fouling can be reduced.


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